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ASSESSMENT OF ARABLE LANDS

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ABSTRACT

One of the dilemmas facing the Asia-Pacific nations is the finding of a solution to the food/population equation. With two-thirds of the world's population inhabiting this region, the critical need for food production efficiency is obvious. However, the agriculturally-related resource information available to food production decision-makers and policy-makers is woefully inadequate. This paper seeks to define the resource information problem, to describe new resource data acquisition and analysis systems, and to propose a research agenda for the Asia-Pacific in the 1980s. The long range objective of the suggested research is to provide a resource information system which can deliver accurate, useful, timely and financially affordable resource information to decision-makers.

THE FOOD/POPULATION EQUATION

Most of the papers presented thus far in this conference have dealt with facts and descriptions of past and current situations as these relate to fertilizer flows and needs in the Asia-Pacific region. This paper will explore the difficult problems related to future fertilizer needs by assessing the arable lands of the Asia-Pacific region.

During the past decade, increasing attention, with frequent expressions of alarm, has been given to the global population/food dilemma. However, even prior to the 1970s over a period of two centuries, thoughtful and concerned persons wrestled with problems related to the carrying capacity of the world. Since 1798, when Thomas Malthus published "An Essay on the Principle of Population," there have been repeated warnings that the human population, subject to exponential increase, could--or at some time surely would--overtake food supplies, which Malthus assumed could increase only arithmetically.

Across the centuries there have been localized famines and some food shortages of wide extent. During this century there were major shortages in the years following World War I, in the late 1940s and early 1950s following World War II, in the mid-1960s after two years of drought on the Indian subcontinent, and in the early 1970s when world grain production dropped 35 million tons. Yet it has been only since 1960 that large numbers of people and national and world leaders began to appreciate the serious and chronic nature of the world food problem.

Even the most optimistic projections give cause for concern in providing food for the global population during the decades ahead.

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There is an urgent need for more accurate and effective food and population information which can carefully monitor significant changes in population and food supply.

Recently, Dudal (1978) summarized the results of numerous studies related to the world's capacity to feed a rapidly expanding population. These studies reveal great differences among the estimates of arable land within a finite total land area. The food production from the world's arable lands is highly variable and is greatly affected by the technology which is used and by the various social and economic conditions which prevail. Moreover, land which is considered arable for cassava or sugarcane may not be suitable for wheat and soybeans. The lands of the world which have been classified as arable represent an exceptionally broad range in potential productivity of food.

According to Dudal (1978) the area of arable land increased by 135 million hectares during the 1957-1977 period, an increase of approximately nine percent of the current 1.5 billion hectares of cultivated land in the world. During the same period the world's population increased from 2.8 to 4 billion, an increase of 40 percent. In terms of increased production, the additional arable land at a low level of agricultural inputs would provide food for only an additional 400 million people. The food supplies for the 800 million additional people have been obtained from an intensification of agriculture on land already under cultivation. This intensification is reflected, in part, by a dramatic increase of annual fertilizer use, from 24 million tons of plant nutrients (N, P_2O_5, K_2O) in 1957 to 88 million tons in 1976/77, and a considerable expansion of irrigation. It is significant, however, that 110 million hectares or 70 percent of the additional arable land was added in developing countries while intensification of production occurred in industrialized nations which consumed 85 percent of the world's fertilizer production.

The food production task in Asia-Pacific then has two vital components or requirements:

- identification, assessment and development of current and potentially arable land, and
- intensification of production on currently cultivated lands.

The remainder of this paper will address the problem of identifying and assessing arable lands.

NEW INFORMATION TECHNOLOGY FOR RESOURCE ASSESSMENT

The past two decades which produced dramatic changes in the global food/population equation have brought equally dramatic changes in our capabilities to survey and monitor the earth surface environment.

In 1948 the British astrophysicist Fred Hoyle wrote: "Once a photograph of the Earth, taken from the outside, is available--once the sheer isolation of the Earth becomes plain--a new idea as powerful as any in history will be let loose."

Soon after being named by President Carter as administrator of NASA, Dr. Robert Frosch (1977) made this observation:

> We are the first generation to see the Earth as a whole. For centuries man has observed and tried to represent by drawings tiny areas of the Earth surface. He would piece these drawings together in an attempt to show what the Earth would look like if he could see it as a whole. A few decades ago he made a great leap forward by inventing the camera, then later placing the camera on aircraft. By these developments man extended his powers of observing the surface of the Earth. He could see much larger areas and less piecing together was necessary. But this is the first generation that has seen data that went the other way. Data which provide a broad synoptic view of the Earth can also be used to extract great details. So in a sense, we have turned the whole enterprise around. Instead of starting with the details and trying to construct the big picture, we now have the capability to go the other way--to look at the big picture and then figure out how to extract the details that explain it.

One of our major concerns in this conference is to see the big picture related to arable lands in Asia and the Pacific and then to analyze the changes necessary to make those lands more productive and to determine how much fertilizer is needed on these arable lands during the next two or three decades. One of the dilemmas we face is that of obtaining information essential to making an accurate, credible assessment of arable lands and fertilizer needs.

For decades scientists have been steadily adding to our understanding of soils, climate, and agricultural production. In fact, ninety percent of all the scientists who have ever lived are working now. And mankind's store of knowledge is doubling at least three times per century. The new technology related to observation and monitoring earth surface features promises to accelerate our knowledge of land, vegetation, and water resources. This may be especially significant in those land areas of the world where there is limited information about the soils and their potential productivity, and about crop response on these soils to different kinds of management.

However, there are many areas in Asia-Pacific where decision makers and policymakers cannot wait for 30 years to double our knowledge of land resources and management systems capable of providing adequate, nutritious food for the expanding populations. Three areas of recent technological developments related to agricultural and food information systems promise to reduce the time to provide essential resource information.

1. Data Acquisition

Major advancements have been made since 1960 in instruments, remote sensing devices, equipment, and sampling strategies for observing, characterizing, and monitoring a target or scene. New data acquisition methods in the laboratory, in the field, from air and space platforms provide new vistas of the earth, never available before, from the sub-atomic structure to thousands of square kilometers in a single synoptic view of the environment at the earth surface.

2. Data Analysis

Traditionally, the ability of the observer, whether scientist or poet, to acquire data has by far exceeded his ability to analyze and interpret data. The computer revolution of the past 25 years has provided a giant leap forward in the human capability to cope with the masses of data which are accumulated. Ruth Davis (1977), writing on the evolution of computers and computing, states: "Computers are properly cited as the first as well as the most important invention ever that significantly extends man's intellectual capabilities. Until the age of computers, inventions had primarily extended our muscular powers as well as certain of our sensory powers."

Davis predicts that the decreasing costs and decreasing size of computers and logical devices will put these scientific artifacts into the hands of large numbers of individuals. Further, man will continue to increase the number of "intelligent" tasks for computers faster than he does for himself.

The computers, or hardware, together with the computer language and analytical programs, or software, which have evolved within the past two decades place at our disposal a "never before" capability to store, retrieve, overlay, analyze, and interpret vast quantities of data. Perhaps this capability provides a new opportunity to explore the relationships between the many complex facets of global food production--physical, biological, chemical, cultural, economic, political, and social.

3. Information Dissemination

The technology of communication is another of man's activities which has undergone revolutionary changes during the past two decades. It is now possible to instantaneously transmit voices, images and large masses of data from any spot to any other place on the surface of the earth.

A development which integrates these three areas of technology is the Earth Resources Observation satellite program. The launch of Landsat 1 by the National Aeronautics and Space Administration (NASA) in July 1972 ushered in a new era of earth observations. Landsats 2 and 3 followed in January 1975 and March 1978, respectively. Landsat D, which will become Landsat 4 after a successful launch, is scheduled to be placed in polar orbit in 1982 followed by Landsat D' in 1983. Landsat 1, 2, and 3 are in near polar, sun synchronous orbit at an altitude of approximately 920 kilometers. The orbital and scanner designs are such that each satellite has the capability of scanning the surface of the earth every 18 days. After five years of successful data acquisition, Landsat 1 was retired from service in January 1978.

The satellites are equipped with return beam vidicon cameras (RBV) and multispectral scanners (MSS). Specifications for Landsats 1, 2, and 3 are summarized in Table 1.

TABLE 1--SPECIFICATIONS OF THE RETURN BEAM VIDICON (RBV) CAMERA AND THE MULTI-SPECTRAL SCANNERS (MSS) ON LANDSATS 1, 2 AND 3.

Landsat	Sensor	Spectral Bands (UM)	Description	Spatial Resolution (M)
1, 2	RBV	0.475 - 0.575	visible blue, green	80
		0.580 - 0.680	visible orange, red	80
		0.69 - 0.83	near infrared	80
3	RBV	0.505 - 0.750		38
1, 2, 3	MSS	0.5 - 0.6	visible green	80
		0.6 - 0.7	visible red	80
		0.7 - 0.8	near infrared	80
		0.8 - 1.1	near infrared	80
3		10.4 - 12.6	thermal infrared	240

Landsat D and D' will have a nominal orbital altitude of 705 km and will maintain a 16-day cycle of repetitive coverage. The MSS of Landsat D and the two on-board sensors (MSS and thematic mapper, TM) of D' will provide ground coverage of about 185 x 170 km per scene. The MSS will obtain data in the same four bands as those on previous Landsats and have the same instantaneous field of view (80 m). The TM, a line-scanning device also, will operate over seven bands and have an instantaneous field of view of 30 meters (Table 2).

TABLE 2--SPECIFICATIONS OF THE THEMATIC MAPPER OF LANDSAT D'

Spectral band (m)	Description	Spatial Resolution (m)
0.45 - 0.52	visible blue	30
0.52 - 0.60	visible green	30
0.63 - 0.69	visible red	30
0.76 - 0.90	near infrared	30
1.55 - 1.75	middle infrared	30
2.08 - 2.35	middle infrared	30
10.40 - 12.50	thermal infrared	120

Data from the Landsat sensors are transmitted to receiving stations in digital form. Receiving stations in operation as of May 1979 include the following:

United States of America (3 stations)

- Greenbelt, Maryland
- Goldstone, California
- Fairbanks, Alaska

Canada (2 stations)

- Prince Albert, Saskatchewan
- Shoe Cove, Newfoundland

Brazil - Cuiaba

Iran - Tehran

Italy - Fucino

Japan - Tokyo

Sweden - Kiruna

Receiving stations are under construction in Argentina, Australia, and India. The common reception radius of ground receiving stations is 2,780 km.

The products available from receiving stations include black and white single-band images, false color (multiband) images, and digital data on computer compatible tapes. These images can be analyzed and interpreted by visual methods or the digital data can be analyzed by computer-implemented pattern recognition techniques.

APPLICATIONS OF EARTH OBSERVATION SYSTEMS FOR ARABLE LAND ASSESSMENT

Since the launch of Landsat 1, agricultural scientists in many nations have used satellite data to inventory and monitor earth surface features related to agriculture production. For the purposes of this paper, the discussion in this section will be restricted to the use of remote sensing technology for assessment of arable land resources.

One of the most obvious agricultural applications is the identification and area measurement of cultivated crops (NASA, 1978). Equally important but somewhat more complex is the use of these techniques to predict crop yields. An increasing research effort is being expended to use remotely sensed data as one of the inputs for improving the accuracy and updating of crop yield predictions.

During the 1970s scientists in increasing numbers have been exploring methods of using satellite-derived images for delineating meaningful soil boundaries and characterizing soil conditions. One of the important uses of Landsat images is as a base from which preliminary soil legends can be described and general soil differences can be mapped. A single satellite image has a particular advantage over aerial photography because it provides a synoptic view of a contiguous area covering 34,000 km^2. This synoptic view is valuable to the soil surveyor in correlating soils mapped in adjacent counties or political units by different surveyors at different times.

Visual interpretation of black and white and false color images produced from Landsat data were used by Westin and Frazee (1976) to produce general soil maps at scales of 1:250,000 or smaller with map units of 260 hectares or larger. Weismiller, et al. (1979) visually interpreted black and white and false color images produced from Landsat data to determine soil parent material boundaries in Jasper County, Indiana (Figure 1). Confirming these boundaries by field observations, they then digitized these boundaries and overlaid them onto the four Landsat MSS bands which had been adjusted to a scale of 1:15,840. Spectral maps delineating soil differences were then produced at this scale with map units as small as one hectare. These maps delineating more than 50 different spectral classes in six different parent material areas are being used by soil surveyors as an additional valuable tool for a detailed soil survey of Jasper County, Indiana (Figure 2).

The digital format of Landsat MSS data permits rapid and easy merging and/or recombination of spectral classes to produce a wide array of smaller-scale base maps for soil survey at different levels of generalization.

There is increasing evidence that Landsat data can be useful for mapping and monitoring land degradation caused by wind erosion, water erosion, salinization and flooding. A striking example of denudation and sand dune encroachment caused by wind action can be seen in an area along the Wadi Abu Habl in Western Sudan (Fig. 3). The same data from which the synoptic view of the area at a scale of 1:250,000 was produced, was also used to examine in detail, at a scale of 1:25,000, the characteristics of the cultivated areas of one of the sand dunes (Figure 4). The three spectral classes of the cultivated sands seemed to correlate well with the areas of millet, peanuts, and fallow.

Severe erosion caused by rainfall has been detected and separated spectrally in the humid temperature region of northern and central Indiana (Figure 5). In these cultivated soils, the exposure of subsoil resulting from severe erosion gives reflectance values measured by the satellite sensors which are considerably different from those of the less eroded surrounding soils.

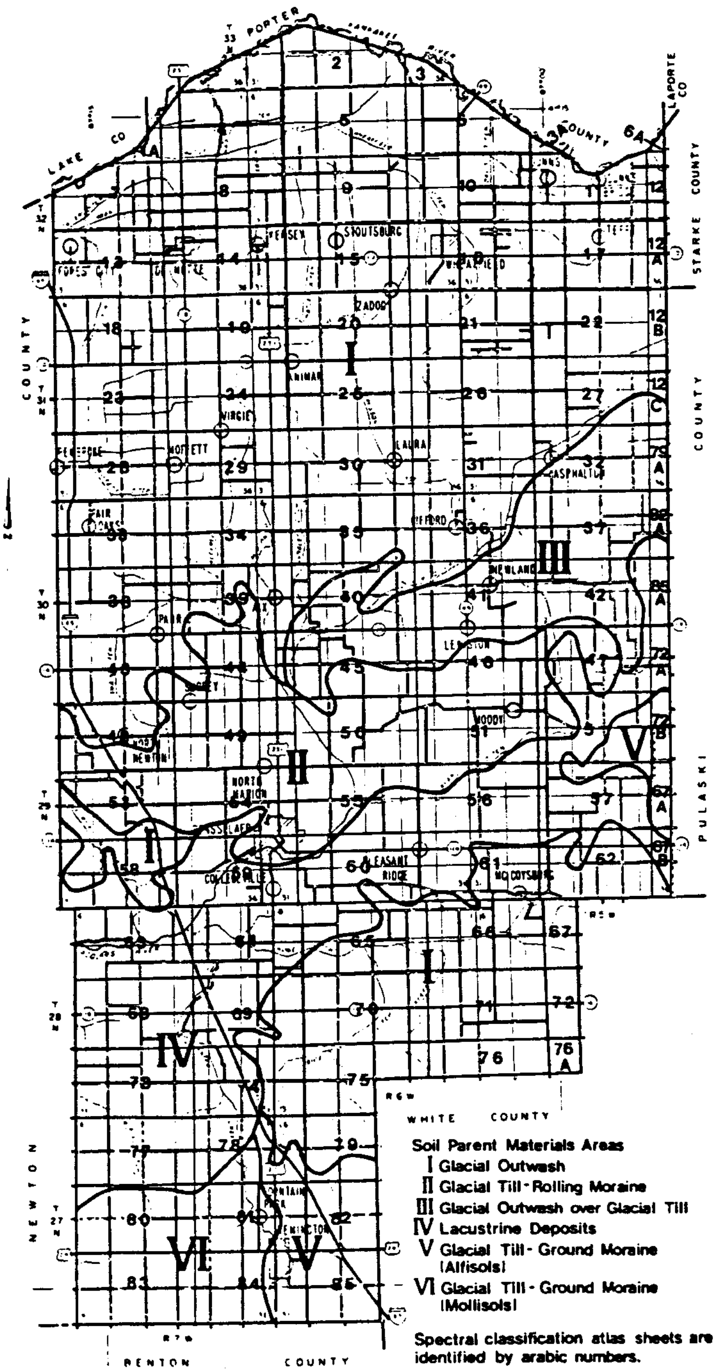
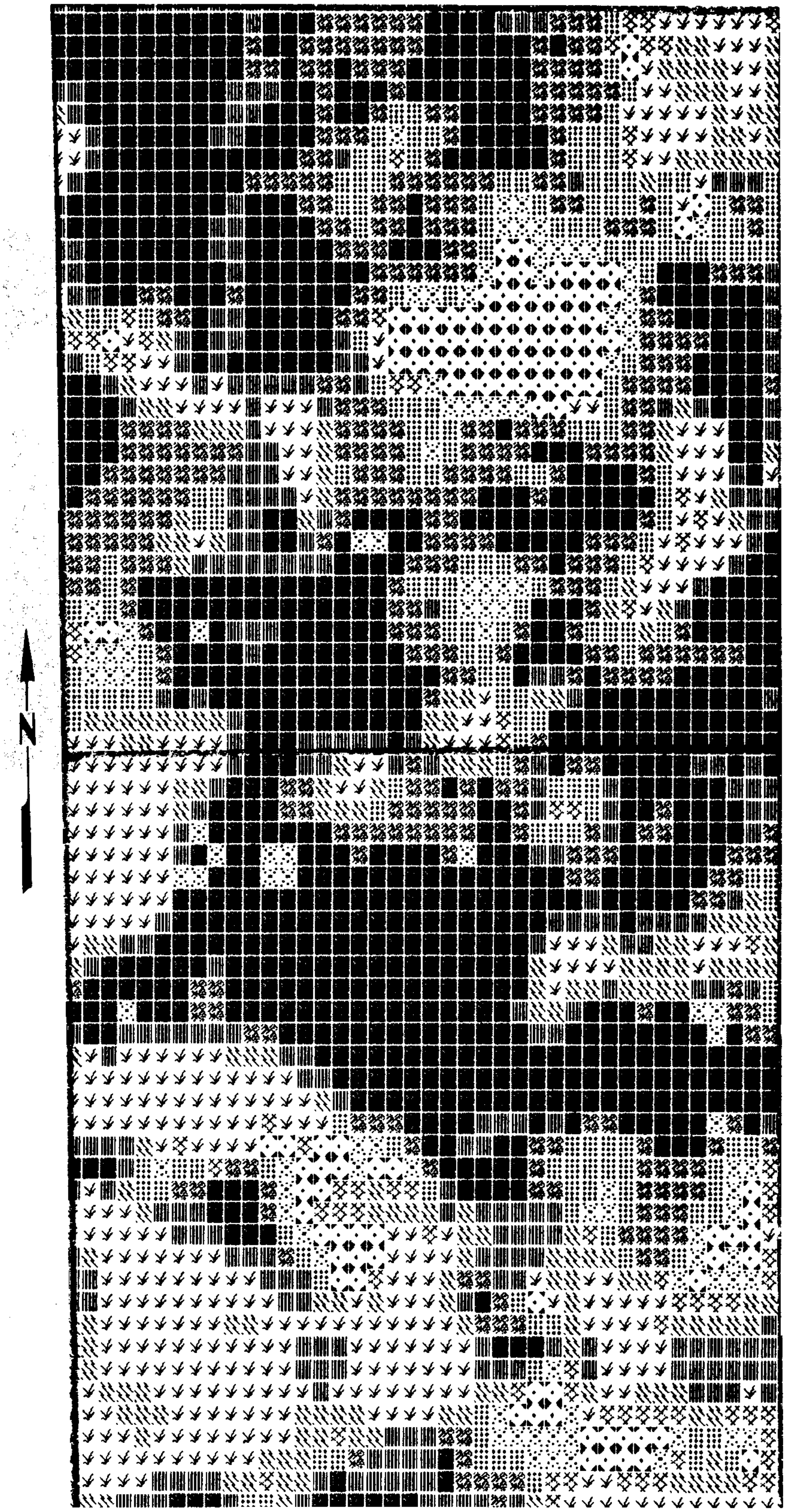


Figure 1. Parent material map of Jasper County, Indiana produced from visual interpretation of Landsat images. Original scale 1:125,000.



LEGEND

Class 1 - Excessively to well drained soils with significant inclusions of somewhat poorly drained soils. Very minor inclusions of very poorly drained soils also occur.

Class 2 - Somewhat poorly drained soils with significant inclusions of both excessively to well drained and very poorly drained soils.

Class 3 - Very poorly drained soils with significant inclusions of excessively to well drained and moderately well drained soils. S/V*

Class 4 - Very poorly drained soils with minor inclusions of excessively to well drained and somewhat poorly drained soils.

Class 5 - Very poorly drained soils with minor inclusions of somewhat poorly drained and excessively to well drained soils. S/V*

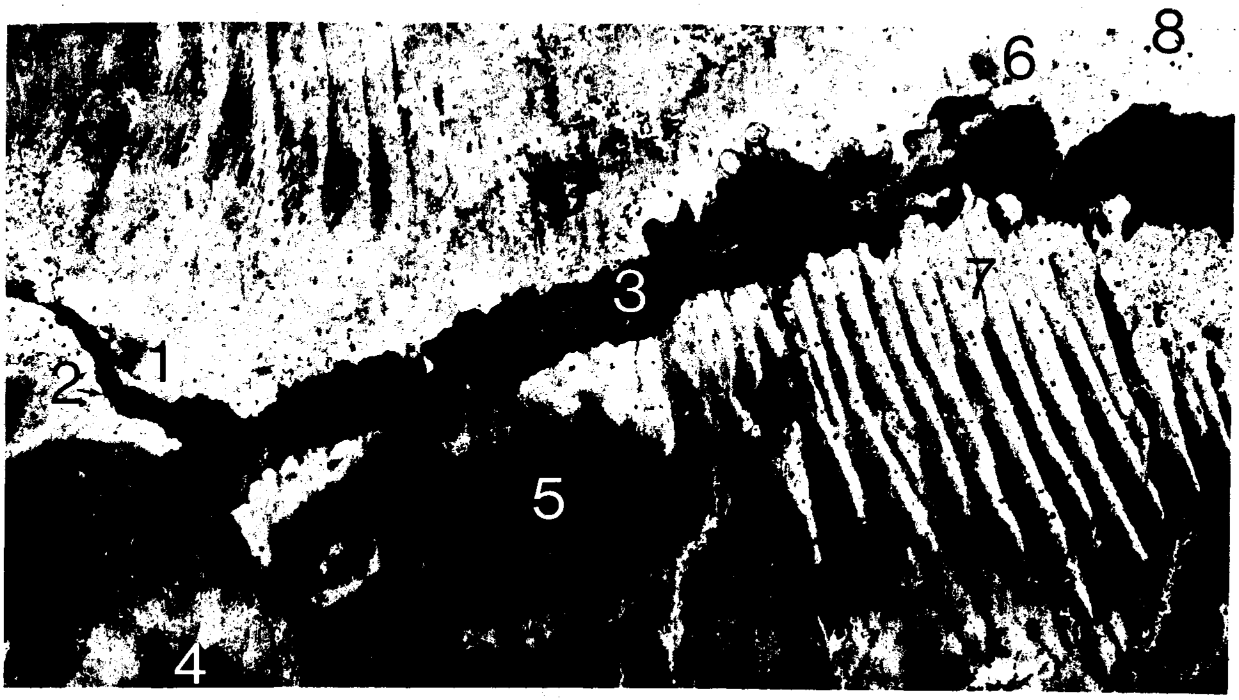
Class 6 - Very poorly drained soils with minor inclusions of somewhat poorly drained soils. Extremely small amounts of excessively to well drained soil inclusions occur.

Class 7 - Very poorly drained soils with very minor inclusions of somewhat poorly drained soils. S/V*

Class 8 - Very poorly drained soils with very minor inclusions of somewhat poorly drained soils.

Class 9 (Vegetation) - Predominantly very poorly drained soils. Significant inclusions of excessively to well drained, moderately well drained and somewhat poorly drained soils occur.

Figure 2. Spectral map delineating soil characteristics of an outwash area in Jasper County, Indiana. Scale 1:15,840



Key to prominent features in landscape:

1. Er Rahad (town)
2. Er Rahad Reservoir
3. Floodplain of Wadi Abu Habl
4. Jebel Ed Dair (granite hill)
5. Upland Clay Plain
6. Umm Ruwaba (town)
7. Sand Dunes
8. Villages

Figure 3. Landsat image showing denuded areas and dune encroachment along Wadi Abu Habl in Western Sudan. Original scale 1:250,000.

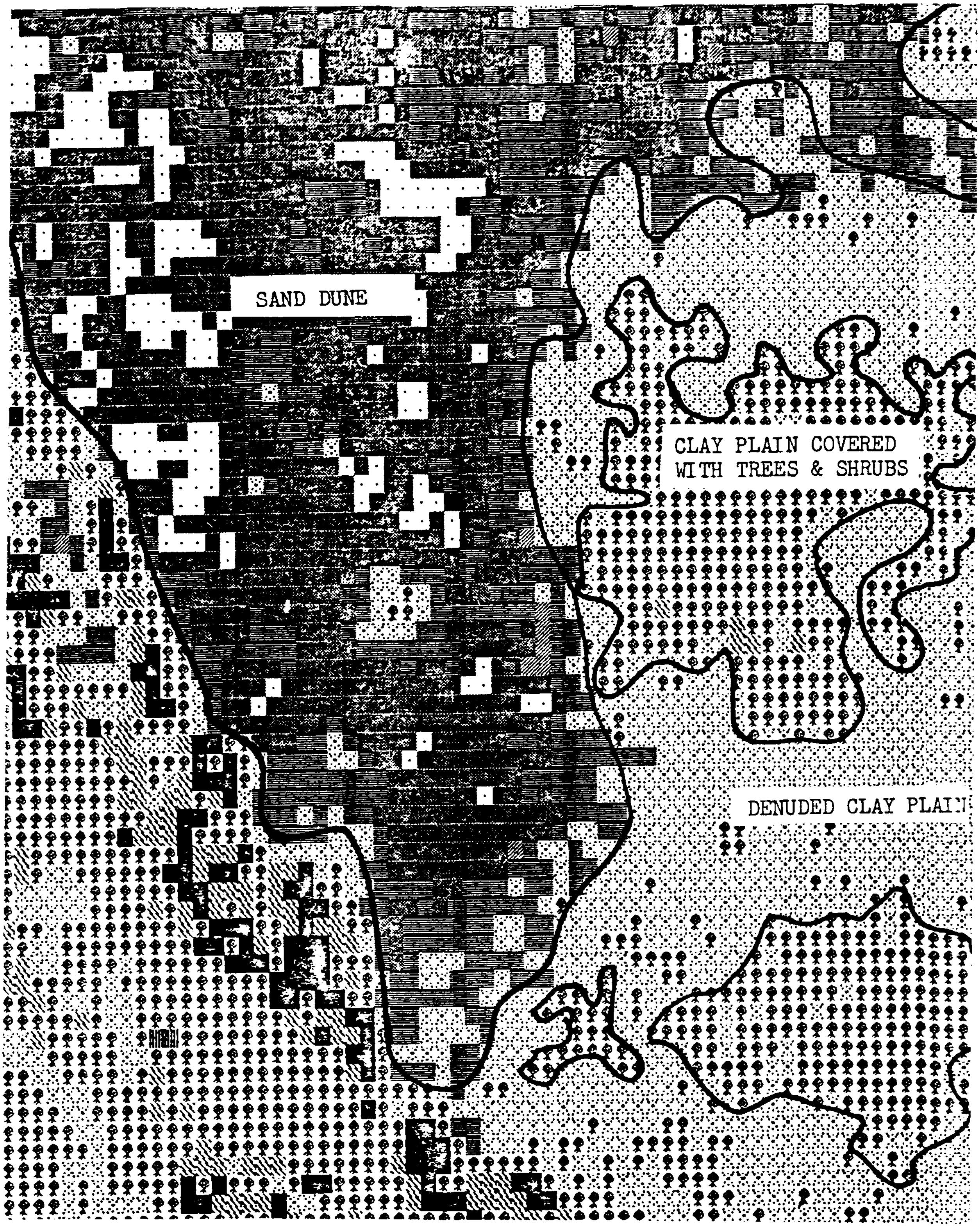


Figure 4. Detailed spectral map of dune area south of Wadi Abu Habl in Western Sudan. Scale 1:25,000.

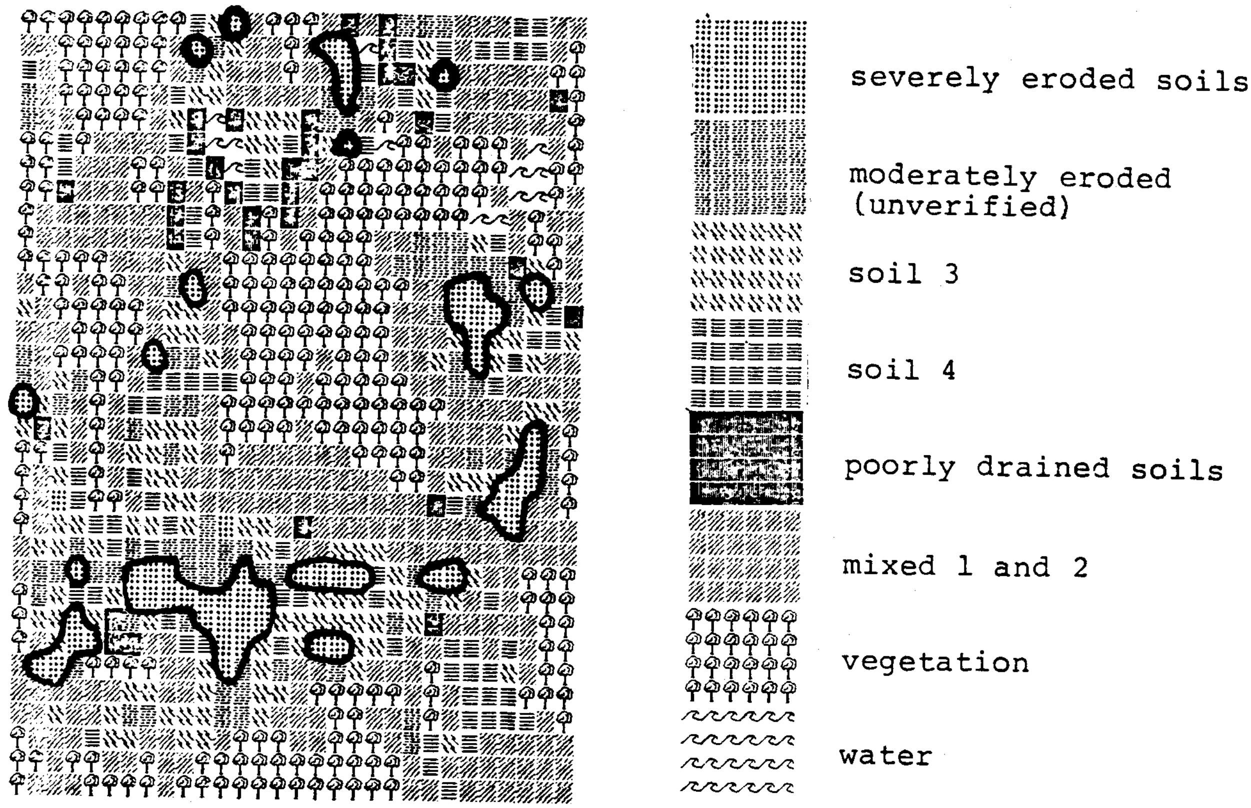
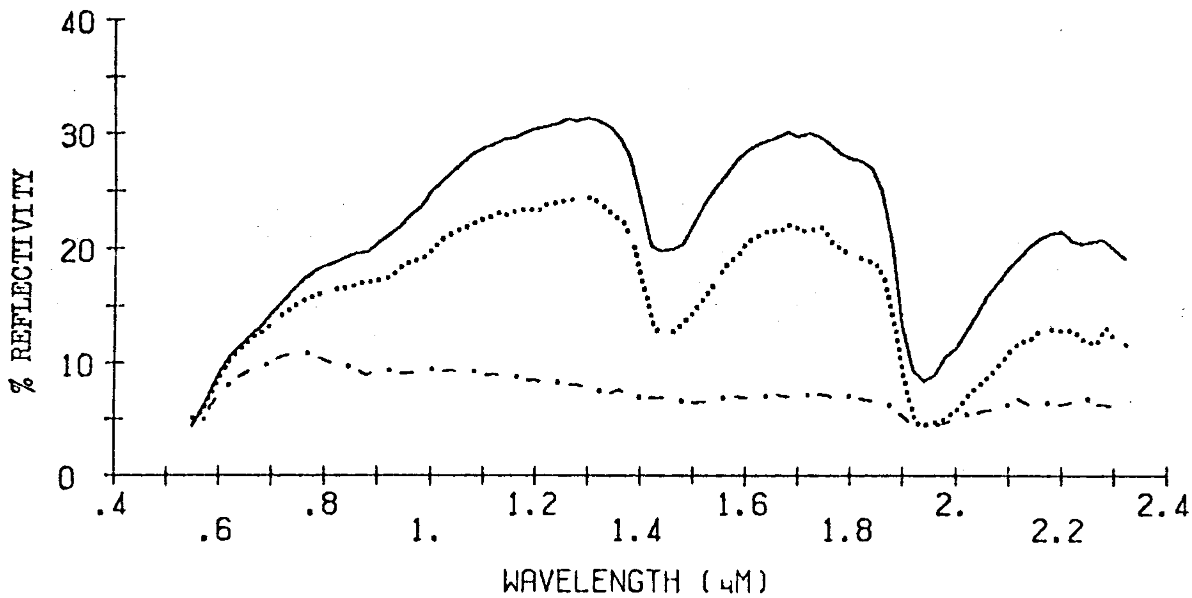


Figure 5. Spectral map units delineating severely eroded soils from other soil and vegetation classes. Scale 1:24,000.

Our ability to interpret spectral measurements obtained by multispectral scanners is greatly dependent upon our understanding of the spectral or reflectance properties of earth surface features--soils, crops, trees, water. Currently, several studies are being conducted to determine quantitative relationships between spectral and other properties of soils. An example of the value of spectral analysis is the comparison of three different soils described by soil surveyors in the field as dark red and assigned Munsell color notations of 2.5 YR 3/6 (Figure 6). Although the differences in visible reflectance (0.4 - 0.7 μm) is not great, the differences in the near and middle infrared (0.7 - 2.5 μm) is dramatic. Similar spectral differences can be shown between severely eroded soils, non-eroded soils, and depositional soils among soils associated in an erosional sequence.

Here is a valuable tool to aid in the delineation of visually similar soils but with wide spectral differences which may be related to texture, internal drainage, water holding capacity, degree of weathering, fertility status, and potential productivity. A concerted research effort should be made to increase our knowledge of these relationships so that remote sensing technology can be used more effectively in the assessment of arable lands and other resources.



Key to Soils Data

Soil	Curve	% Organic Matter	% Fe_2O_3
Dill (Oklahoma, USA)	——	0.6	0.87
Arroyo (Spain)	••••	1.28	2.00
Londrina (Brazil)	•–•–	2.28	25.6

Figure 6. Reflectance curve for three dark red surface soils having moist Munsell color notations 2.5 YR 3/6. (Stoner, 1979)

FUTURE APPLICATIONS IN ASIA AND THE PACIFIC

Although many countries in the Asia-Pacific region have applied remote sensing technology in a variety of ways to study their resources, its use is still quite limited. With the overriding purpose of extending our body of knowledge of the land resources and potential agricultural productivity and fertilizer needs of the Region, the author proposes the following research program to be conducted in the 1980s.

1. Objectives

a. To determine the degree to which Landsat multispectral scanner (MSS) and return beam vidicon (RBV) data can be used to delineate differences in the quantity and quality of land, vegetation, and water resources in Asia and the Pacific.

b. To examine and assess the use of Landsat MSS images as base maps for the inventorying of land, vegetation, and water resources at scales from 1:25,000 to 1:1,000,000.

c. To use sequential Landsat MSS data to make quantitative assessments of seasonal and yearly changes in the landscape (land use, arable lands, land degradation, wetlands, cultivated crops, forest resources, rangelands).

d. To define the desired specifications (spatial resolution, spectral bands, frequency) of sensor systems of future earth observation satellites to meet the data needs for the management of arable lands, forest lands, rangelands, and surface water resources in Asia and the Pacific.

2. Background and Justification

In many of the developing countries, the existence and/or ready availability of resource surveys is severely limited. In some countries which have received technical assistance from a variety of donor countries, as many as eight different soil classification systems at as many different scales and levels of mapping detail have been used to survey different areas. Case after case can be cited in extensive, costly development projects where critical decisions related to changes in land use had to be made with little or no detailed information about the soils and hydrologic characteristics of the projected areas. Such information is an essential ingredient in the prediction of the consequences of changing land use. In many instances, this lack of resource information has resulted in failure of the project, sometimes with disastrous effects.

Many areas of very high population density in Asia and the Pacific face critical decisions concerning changes designed to extract greater food resources from the land. Mass transfer of people from one area to a less densely populated area is in progress or is being contemplated by several developing countries. Unless accurate, useful, and timely information about the land, vegetation, and water resources to undergo change is available and is used wisely by the decision makers, serious unanticipated complications may lie ahead.

Conventional methods of inventorying and monitoring changes in earth resources are tedious and slow. In many areas under extreme population stress, there is insufficient time for conventional survey methods to provide the required resource information and to respond to the needs for basic data.

Even though the current Earth Observation Satellite program of NASA is still experimental in concept, many countries are using MSS images and data as a basis for surveying their land, vegetation, and water resources. Most of these maps are being prepared at scales of 1:100,000 or smaller and are being accomplished primarily by visual analysis. In many instances this scale is less than adequate for local and subnational planning.

Digital analysis techniques, even though they require a more sophisticated system of analysis, offer many benefits. Results are quantitative; a very wide range of spectral separations can be made rapidly; where the need arises, spectral classes can be combined or further divided into subcategories; tabular information related to areal measurements of specific classes can be quickly generated; digital data bases can be established and registered to other sources of data which can be related geographically to the addresses represented by the satellite data at scales as large as 1:25,000.

To date, the use of Landsat data in the digital format has been limited in the Asia-Pacific region. In the realm of earth resources data, the world is moving rapidly in the direction of digital data bases. With the launch of Landsat D in 1981, the flow of earth resources data transmission will increase from 1.1 million data points per second of Landsat 3 to more than 15 million data points per second from Landsat D. How can the nations of Asia and the Pacific take advantage of this valuable data source and extract from it a maximum of useful information?

A carefully designed research program must be conducted to determine the utility of Landsat data in identifying and characterizing features of interest in the landscape.

3. Approach

A study such as the one proposed could be approached at different levels. The approach suggested is a rather ambitious one and would require careful planning and coordination plus the commitment and cooperation of a number of scientists in the Asia-Pacific countries in which test sites are located. The general approach would be to obtain detailed agronomic, meteorological, and spectral data on small research plots of major crops at national agricultural experiment stations. Data would be obtained less intensively for larger sites of commercially grown crops and forest lands. A minimum project duration of five years would hopefully provide the possibility of obtaining cloud free multispectral data over the test sites on several different dates by both Landsat 3 (80 meter resolution) and Landsat D (30 meter resolution) scheduled for launch in 1981.

During the project, field observations and aircraft/satellite data could be acquired throughout at least three crop growing seasons at each test site. The final year of the project would be designated for intensive statistical analysis and interpretation.

a. Test sites. In the choice of test sites, several factors must be considered--political climate, availability of local experts, local institutional arrangements, experience in cooperative regional research, local interest in an in-depth assessment of land, crop, forest, and water resources by remote sensing techniques.

b. Agronomic data to be collected.

- o soils for each test site (Experiment Station)
  - site description (taxonomy, parent material, climatic regime)
  - profile description
  - chemical properties of surface soils (organic matter content, iron oxide content, mineralogy)
  - physical properties (color, % sand, silt, clay)
- o soils for extensive test sites (commercial fields, forest lands)
  - detailed soils map where possible
  - topographic map, 10 m or less vertical intervals (if available)
- o crop data (for all plots in Experiment Station test sites; sampling of extensive areas)
  - date of planting
  - general crop calendar
  - fertilizer treatments
  - cultivar
  - dates and amount of irrigation
  - plant measurements to be obtained every two weeks during growing season

    height of plant

    percent soil cover

    leaf area index

    biomass (above ground)

    plant water content

c. Spectral, photographic data

- o laboratory/field spectroradiometer data
- o ground photography (color, color infrared)
- o air-borne spectroradiometer (low altitude aircraft or helicopter) data
- o aerial photography (color, color infrared)
- o multispectral scanner data from Landsats 1, 2, 3, and D
- o return beam vidicon data from Landsat 3

4. Organizational Arrangements

An effective administrative and implementation organization will have to be developed to make it possible to accomplish the objectives of this project. There must be a large component of coordination to assure the essential participation of and communication among scientists and policymakers from numerous national ministries and research institutes and international development organizations.

5. Project Personnel

The project objectives can be met by a staff consisting of a small overall administrative team, with a coordinator in each participating country in which test sites are located. Much of the field research, analysis, and interpretation could be done by graduate students from participating countries enrolled for graduate studies in crop physiology, statistics, forestry, soil science, ecology, geography, or some related field.

THE CHALLENGE

Several references have been made to the spatial resolution of the satellite sensors. That is, what is the smallest ground area identifiable in the satellite-derived data? In our research we often refer to temporal resolution, that is, the frequency of repetitive scanning of the same scene. We also speak of spectral resolution, meaning the number and width of wavelength bands measured by the sensors.

What has not been addressed may be clustered into a broad but very important category--the political/social/economic resolution. The potential benefits to the human family of a global earth resources information system are indeed exciting. The technology is with us and continues to develop at an accelerated rate.

But, perhaps the most important issues have yet to be resolved. What is the "resolution" of our political, social, and economic "scanners" as we attempt to design a global information system which will provide optimum benefits to the citizens of all nations? How do we internationalize such a system so that all nations may participate and reap the benefits? How do we effectively transfer the technology so that all nations may be equipped to use the system? Can we have a global resource information system which does not erode the sovereignty or invade the privacy of nations? These and many more questions are yet to be resolved.

If we are to be prepared in the Asia-Pacific region to take full advantage of the developing resource information technology, it is of critical importance that sound research programs be conducted in this area to establish quantitative relationshps between those measurements obtained by aerospace sensors and important categories of ground information.

The challenge is before us. There is so little time and we have so much to do!

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